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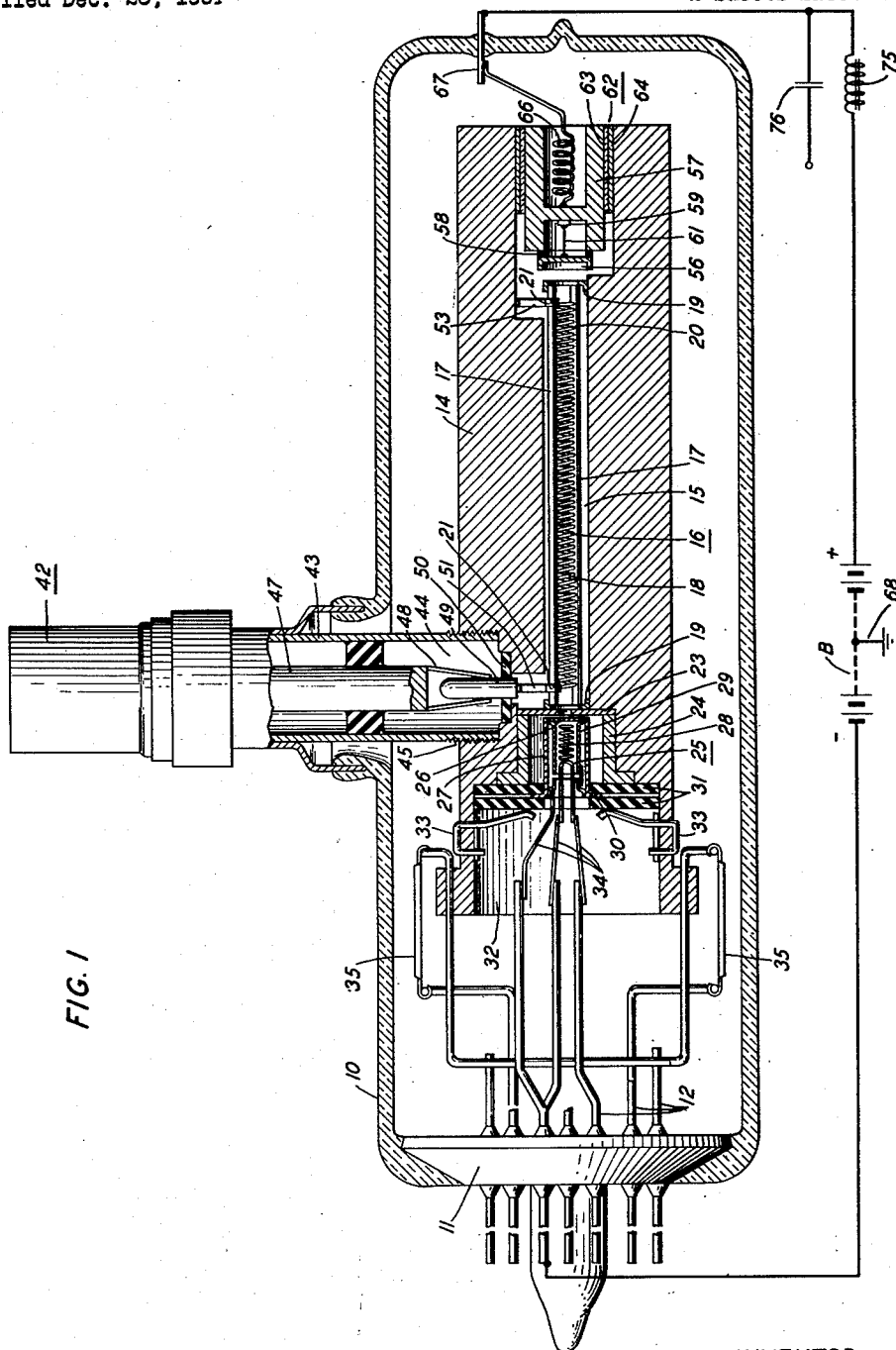
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2,801,358

ELECTRON DISCHARGE DEVICES

Filed Dec. 28, 1951

2 Sheets-Sheet 1



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FIG. 2

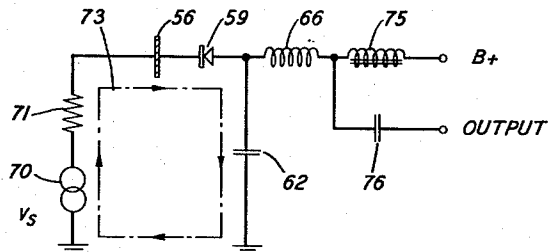


FIG. 3

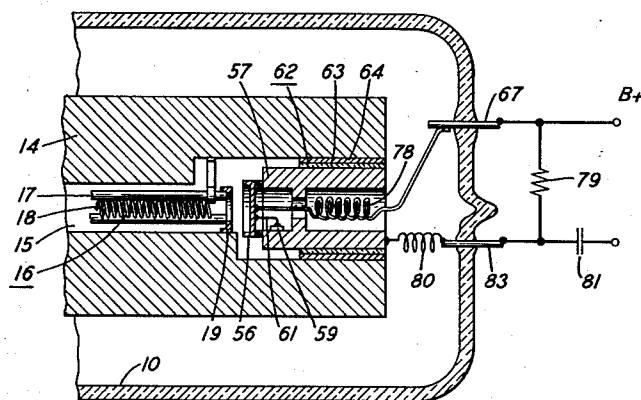
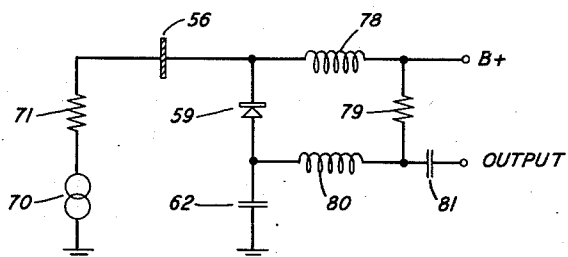


FIG. 4



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ELECTRON DISCHARGE DEVICES

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10 Claims. (Cl. 315—3.5)

This invention relates to electron discharge devices and more particularly to such devices known as traveling wave tubes.

Such devices are employed for the amplification of a signal which has been superimposed on a high frequency carrier. Priorly, the carrier and signal have been introduced to the device through a suitable terminal at the input whereby proper coupling to the helix may be attained, amplified by the interaction of the electromagnetic waves of the signal coupled to the helix and the electron beam projected along the helix, and then removed from the device by another suitable coupling to an output terminal. Demodulation and detection of the signal have then been performed by apparatus external to the device.

It is one object of this invention to obtain directly from a traveling wave type device a demodulated signal corresponding to the modulation on the carrier at the input of the device.

It is another object of this invention to reduce to a minimum feedback from the output of the device to the input of the device.

It is a further object of this invention to demodulate the carrier within the same envelope of the device as close to the interaction space or amplifying section as possible.

A still further object of this invention is to provide an improved traveling wave tube.

These and other objects of this invention are attained in accordance with this invention by the positioning of a rectifier element directly adjacent the collector of the device and between it and the output terminal. More specifically, in one illustrative embodiment of this invention, a rectifier is electrically connected between the collector electrode and an anode member, so that a voltage difference appears across the rectifier dependent on the flow of electrons to the collector. The anode member is biased positive with respect to the cathode and connected thereto by a direct current connection. Choke and capacitance means are provided to by-pass the high frequency carrier so that only the demodulated signal appears at the output.

In another specific embodiment of this invention, the rectifier is electrically connected between the collector electrode and the anode element but the direct current connection is made directly to the collector electrode, a voltage bias thus being interposed between the collector electrode and the cathode. Choke means is provided to prevent appearance of the modulated signal in the bias voltage supply and a capacitance is connected between the rectifier and ground so that a voltage corresponding to the envelope of the carrier wave can be taken directly from the output terminal of the device.

In each of these specific embodiments the capacitance is advantageously provided by an insulating layer, as of glaze, directly on the outer surface of the anode member and forming the dielectric of the capacitance. A metallic layer encompasses the insulating layer and together with the anode element provides the plates of the capacitance.

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Further in each of these specific illustrative embodiments of this invention, the collector and demodulating assembly is a complete unit that may be positioned at the collector end of the traveling wave tube. More particularly, in each of these specific illustrative embodiments, the collector and demodulator assembly is positioned within a metallic housing encompassing and shielding the helix and interaction space of the traveling wave tube. The housing advantageously is grounded, as by being connected to the outer conductor of a coaxial input terminal.

Thus in accordance with this invention the output signal is taken from the modulated electron beam and not from the electromagnetic wave coupled to the helix, the electron beam impinging on the collector electrode and being demodulated within the envelope of the device as described further below.

It is therefore one feature of this invention that means be provided within the envelope of the traveling wave tube to demodulate the signal imposed on the electron beam by the applied carrier during the interaction of the beam and the carrier along the helix. More specifically, it is a feature of this invention that a rectifier element be electrically connected between the collector electrode on which the electron beam impinges and the output terminal of the device.

It is a further feature of this invention that the rectifier element be positioned and electrically connected between the collector electrode and an anode element.

It is a further feature of this invention that the anode element support the collector electrode and be positioned within a metallic housing which shields the electron beam. Further it is a feature of this invention that a by-pass condenser be provided by a layer of a dielectric material on the outer surface of the anode element and more specifically that the condenser be provided by that layer of dielectric material interposed between the anode element and the metallic housing. Further in accordance with this specific feature of this invention the anode element and collector electrode are supported from the housing by this interposed condenser.

It is a further feature of this invention that a choke element or coil be positioned within the anode element. More specifically, in accordance with this feature of this invention, in one specific embodiment, the coil may be a high frequency choke cooperating with the by-pass condenser to prevent appearance of the high frequency carrier in the output signal.

A complete understanding of this invention and of the various features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a sectional view of an electron discharge device of the traveling wave tube type illustrative of one specific embodiment of this invention;

Fig. 2 is an equivalent circuit for the device of Fig. 1 illustrating particularly the demodulation of the signal in accordance with this invention;

Fig. 3 is a partial sectional view of another electron discharge device illustrative of another specific embodiment of this invention, showing particularly the collector and demodulator assembly therefor; and

Fig. 4 is an equivalent circuit for the device of Fig. 3.

Referring now to the drawing, Fig. 1 shows a traveling wave tube illustrative of one embodiment of this invention. This embodiment comprises an envelope 10 as of glass and having a base 11 through which extend a plurality of leads or terminals 12. Situated within the envelope 10 is a metallic housing 14 having a central bore 15 in which is positioned the helix assembly 16. The helix assembly 16 comprises advantageously a plurality of support rods 17 which may be of a ceramic material

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and to which the helix 18 is secured, as by a glaze. The rods 17 advantageously are held in position within the center bore 15 by support rings 19 which are secured to the housing 14 in the center bore 15. Attenuation may be added to the helix by depositing thereon a lossy material, as is known in the art, and additional attenuation is placed at the one end 20 adjacent the collector assembly. The attenuation at the end 20 is graduated so as to be greatest directly at this end of the helix, as described further below. Each end of the helix 18 is secured to a ring member 21 attached to one of the support rods 17.

A grid 23 is held in position against the support ring 19 at the input end of the helix by a flanged ring member 24 secured to the housing 14 in an expanded portion of the center bore 15. An electron gun assembly 25 extends into the flanged ring member 24 and comprises a cathode 26 adjacent the grid 23. The cathode 26 is supported by a cup member 29 in which is positioned a heater element 28. The cathode cup member 29 is in turn supported by a heat shield 27 having a flanged base portion 30 which is held in position between two cathode support insulators 31 situated within a cup-shaped depression 32 at the end of the housing 14 communicating with the enlarged portion of the center bore 15. A plurality of spring members 33 extending through the wall of the housing 14 and into the cup-shaped depression 32 bias the cathode support insulators 31 against the housing 14 and maintain the cathode cup 27 and shield 29 in position. Appropriate connections are made by leads 34 connected to the terminals 12. And a plurality of getters 35 may advantageously be supported between two of the leads 12.

The input signal, which may be a modulated carrier, is coupled to the helix 18 by a coaxial input terminal 42. The terminal 42 may advantageously comprise an outer cylinder 43 threadably engaging a mating aperture 44 in one outer side of the housing 14. The center conductor of the coaxial terminal 42 comprises a center rod 47 having spring fingers 48 fitting over a pin 49 which is supported by an insulating disc 50 in the base of the aperture 44 in the housing 14. A strip of metal 51 is connected, as by welding, to the ring 21 on the support rod 17 and to the pin 49.

The modulated carrier signal is amplified by the interaction of the electromagnetic fields of the signal and the electron beam projected through the helix, as is known in the art. The signal on traveling through the interaction space modulates the electron beam so that the signal appears both on the electromagnetic waves which may be considered as being guided by the helix and the electron beam; signal amplification occurs with respect to both the electromagnetic waves and the beam. Priorly, in traveling wave tubes employed merely as amplifiers, the signal appearing on the beam has been ignored while the amplified modulated carrier is taken off the helix by an appropriate terminal connection coupled to the helix, as by a coaxial terminal attached to the helix similar to the input coaxial terminal 42. However, in accordance with a feature of this invention, the amplified and modulated electron beam is employed to carry the signal to the output connections. The amplified carrier or electromagnetic wave may be removed from the tube by an appropriate output terminal or, as depicted in this specific embodiment of the invention, a graduated attenuation may be positioned at the end 20. This attenuation, which may be a lossy material deposited directly on the helix itself, increases to its maximum directly at the end of the helix and gradually attenuates the carrier to zero on the helix. A strip of metal 53 may advantageously be connected, as by welding, to the ring 21 on the support rod 17 at the collector or output end of the helix and to the metallic housing 14, which is at ground potential. Alternatively the strip 53 may be omitted so that a direct current voltage may be applied to the helix for beam acceleration or other purposes.

The collector and demodulator assembly in the specific

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illustrative embodiment of Fig. 1 comprises a collector electrode 56 which is positioned from an anode member 57 by an insulating ring 58. The anode member 57 advantageously has recesses therein extending from each end. In the recess adjacent the collector electrode 56, a rectifier element 59 is positioned and electrically connected between the collector electrode 56 and the anode member 57. Advantageously, the rectifier element 59 may be secured directly to the anode member 57 and connected to the collector electrode 56 by a short lead 61. The rectifier element 59 may advantageously be a silicon, germanium, or other type of crystal rectifier for high frequency use and is positioned so as to allow passage of the high frequency signal from the collector electrode 56 to the anode member 57.

The anode member 57 is positioned in an enlarged portion of the center bore 15 and separated from the wall of that enlarged portion by a condenser element 62 comprising a layer of an insulating material 63, such as glass or other suitable ceramic, which provides the dielectric of the capacitance and a metallic layer 64 which is directly secured to the housing 14. The metallic layer 64 may alternatively be omitted and the plates of the capacitance provided directly by the housing 14 and the anode member 57, but the provision of the metallic layer 64 facilitates the fabrication of the collector and demodulator assembly as a unit.

A choke element 66, comprising a few turns of wire, is positioned within the other aperture in the anode member 57 and is directly connected thereto. The other end of the choke element 66 is connected to a terminal pin 67 extending through the envelope 10 of the tube.

The operation of this assembly in demodulating the signal may be best understood with reference to the equivalent circuit shown in Fig. 2 wherein the electron gun, providing the electron beam, and the helix interaction of the beam with the introduced modulated carrier are considered to be equivalent to a signal generator 70 of an E. M. F. V_s and internal resistance 71 of a value R . One side of the hypothetical signal generator 70 is grounded and the other side of the signal generator is considered as connected through the collector 56 to the rectifier element 59. This connection is actually provided by the electron beam and the lead 61. The other side of the rectifier element 59 is connected to ground through the capacitance 62. The ground in this case is actually the grounded housing 14 which provides a shielding around the electron beam. The high frequency current path may then be drawn as indicated by the dotted line 73 and can be considered as flowing in the direction indicated, considering the physical flowing of the electron beam rather than the direction of flow of conventional current.

The coil 66 is connected to the intersection of the rectifier element 59 and the capacitance 62, which intersection is actually the anode element 57. The coil 66 provides a high frequency choke and cooperates with the capacitance 62 in preventing the high frequency carrier, which has been imposed on the electron beam, appearing in the modulation output. External to the envelope 10 the direct current voltage bias for the anode element 57 is provided by a voltage supply B+ connected between the anode element 57 and the cathode 26 and provides a direct current connection therebetween. The anode element 57 is thus maintained at a higher potential than the cathode 26. As the cathode 26 is advantageously negative with respect to ground, the anode element 57 may be at ground potential or above. A connection 68 is advantageously made to the voltage supply B connecting it to ground at an appropriate point depending on the voltage of the anode with respect to ground. The positive side of the voltage supply B is connected to the anode element 57 through a second coil or choke element 75 to the coil 66, and, as shown in Fig. 1, actually to the terminal pin 67. This coil 75 prevents the demodulated signal

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from going to the voltage supply B. The output is taken from the coil 66 through a condenser 76 which blocks the voltage supply B, as shown.

When no electron beam is impinging on the collector electrode 56 the collector electrode will be at approximately the voltage of the anode element 57, which is biased with respect to the cathode 26 by the voltage supply B. When electrons impinge on the collector electrode 56, the collector voltage will fall. As the crystal rectifier is connected so as to allow passage of current when the anode element 57 is more positive than the collector electrode 56, a current will flow through the rectifier and to the signal output. The voltage across the rectifier 59 will depend on the magnitude of the electron beam current at that moment. As the electron beam has been modulated by the signal on the applied carrier, the electrons will be bunched in accordance with the signal. Due to the non-linearity of the current-voltage characteristic of the rectifier for low voltages demodulation occurs and the original signal is taken off at the output.

In a modification of the specific embodiment of this invention depicted in Fig. 1, demodulation may be aided by employing a second rectifier element connected in parallel with the rectifier 59 and of opposite polarity and mixing in a high frequency signal from a local oscillator. The interaction at the non-linear rectifiers between this local oscillator signal and the signal amplified by the traveling wave tube then produces the demodulation.

An alternative arrangement of the elements of the collector and demodulator assembly is shown in the specific embodiment of this invention depicted in Fig. 3. For ease of understanding the like elements have been identified by the same reference numerals employed for the illustrative embodiment of Fig. 1. In this embodiment, the voltage bias with respect to the cathode provided by the B supply is applied directly to the collector electrode through a high frequency choke coil 78 situated within the anode element 57. The anode element 57 is connected by a high frequency choke coil 80 to a terminal 83 extending through the envelope 10. External to the envelope a high resistance 79 is connected between the terminals 67 and 83 and the modulation output is taken from a terminal connected to the terminal 83 by a coupling condenser 81.

In the operation of this circuit, as shown in the generalized circuit diagram of Fig. 4, a direct current voltage bias is applied from the B+ supply directly to the collector electrode 56 through the high frequency choke coil element 78 situated within the anode element 57. When no input signal is applied there is a steady state direct current flowing from the B+ supply through the tube. When a signal is applied the electron stream is modulated by a bunching of the electrons. This bunching will cause the current to vary, in accordance with the modulated signal and the carrier, around the direct current steady state condition. The voltage across the rectifier element 59 will therefore also vary. However, whereas in the embodiment illustrated in the equivalent circuit of Fig. 2, the rectifier element was biased so as to always conduct and so that the voltage variations never changed the sign of the potential across the rectifier, in this embodiment, the voltage variations are around a zero voltage value so that the sign of the potential across the rectifier will vary with the voltage variations and the rectifier only conducts during a portion of the carrier frequency cycle.

When the voltage across the rectifier element 59 is of the proper sign to allow current to flow through the rectifier element, the condenser 62 will tend to be charged up to the value of the instantaneous voltage at the collector electrode 56. While the condenser 62 is being charged up on the charging half-cycle there is some leakage through the resistance, but the resistance and capacitance are of such values that the current leaking off during the charging half-cycle is always appreciably less

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than the charging current. This will cause the voltage at the point of intersection of the rectifier element 59, condenser 62, and high frequency coil 80 to follow the modulating signal or the envelope of the carrier, as is well known in the art. In turn a current corresponding to this voltage is applied through the high frequency coil and the condenser to the modulation output terminal.

The high frequency coil 78 prevents the appearance of the signal in the B+ voltage supply. The high frequency coil 80 similarly prevents the appearance of the carrier signal directly on the modulation output terminal and enables the condenser 62 to charge up, as described above. The condenser 81 may advantageously be placed in the modulation output circuit to prevent the appearance of any direct current bias that may be present in the associated circuits appearing across the rectifier within the tube.

It should be noted that in the embodiment of the invention disclosed in Figs. 1 and 2 the demodulation occurs because of the non-linearity of the rectifier element 59, there being at all times a current flow through the rectifier element. However, in the embodiment of the invention disclosed in Figs. 3 and 4 the demodulation occurs because of rectification of the carrier wave, there being a current flow through the rectifier for approximately between a quarter and a half of a cycle at the carrier frequency.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An electron collector and demodulator assembly for traveling wave tubes comprising a collector electrode, insulating means, an anode element supporting said collector electrode through said insulating means, a high frequency rectifier element positioned between said collector electrode and anode element and connected therebetween, and a condenser comprising the outer surface of said anode element, a layer of an insulating material thereon, and a metallic layer over said insulating layer.

2. A traveling wave tube comprising a helical wave conductor, electron gun means including a cathode for projecting a beam of electrons along said conductor, input means for introducing a signal to said conductor, an electron collector electrode to the other side of said conductor than said electron gun means, a cylindrical anode element having a recess therein, insulating means supporting said collector electrode from said anode element adjacent said recess, rectifier means within said recess and electrically connected between said collector electrode and said anode element, a layer of an insulating material on the outer surface of said anode element, a metallic member on said insulating layer, said anode element, insulating layer, and metallic member defining a condenser, means for applying a potential bias with respect to said cathode to said anode element, and means connected to said anode element for taking the signal therefrom.

3. A traveling wave tube comprising a metallic housing having a central bore therein, a helical wave conductor, means positioning said conductor within said bore, electron gun means to one side of said conductor for projecting an electron beam therealong, said electron gun means including a cathode, means for coupling an input signal to said conductor, and a collector and demodulator assembly to the other side of said conductor and positioned in an enlarged portion of said central bore, said assembly comprising a collector electrode, a cylindrical anode element having a recess therein, an insulating ring supporting said collector electrode from said anode element adjacent said recess, a rectifier element within said recess and electrically connected between said collector electrode and said anode element to offer a low

impedance for passage of current when said anode element is at a higher potential than said collector electrode, a layer of an insulating material on the outer surface of said anode element and between said anode element and the inner wall of said enlarged portion of said central bore, said anode element, insulating layer, and housing defining a condenser between said anode element and said housing, and output means connected to said anode element for taking the modulation signal therefrom.

4. A traveling wave tube in accordance with claim 3 wherein said anode element has a second recess therein and comprising a choke coil within said second recess and connected to said anode element, said output means being connected to said choke coil.

5. An electron discharge device comprising electron gun means for producing an electron beam, said electron gun means including a cathode, means for introducing a signal to said beam, means for amplifying said beam, a collector electrode on which said beam impinges, an anode element having an aperture therein, insulating means supporting said collector electrode from said anode element adjacent said aperture, a rectifier element within said aperture and electrically connected between said collector electrode and said anode element, capacitance means having one side connected to said anode element and having the other side at ground potential, and output means connected to said anode element for taking the modulation signal therefrom.

6. An electron discharge device in accordance with claim 5 wherein a choke coil is positioned within said aperture and connected to said collector electrode.

7. An electron discharge device in accordance with claim 6 wherein said output means includes a high frequency choke coil having one side connected to said anode element and having the other side connected to a high resistance.

8. A traveling wave tube comprising a helical wave conductor, electron gun means including a cathode for projecting a beam of electrons along said conductor, input means for introducing a signal to said conductor, an electron collector electrode to the other side of said conductor than said electron gun means, a cylindrical anode element having an aperture therethrough, insulating means supporting said collector electrode from said anode element, rectifier means within said aperture and electrically connected between said collector electrode and said anode element, a layer of an insulating material on the outer surface of said anode element, a metallic member en-

compassing said insulating layer, said anode element, insulating layer, and said metallic member defining a condenser, and output means connected to said anode element for taking off the modulated signal therefrom.

9. A traveling wave tube comprising a metallic housing having a central bore therein, a helical wave conductor, means positioning said conductor within said bore, electron gun means to one side of said conductor for projecting an electron beam therealong, said electron gun means including a cathode, means coupling an input signal to said conductor, and a collector and demodulator assembly to the other side of said conductor and positioned in an enlarged portion of said central bore, said assembly comprising a collector electrode, a cylindrical anode element having an aperture therethrough, an insulating ring supporting said collector electrode from said anode element adjacent said aperture, a rectifier element within said aperture and electrically connected between said collector electrode and said anode element to offer a low impedance to the passage of current when said anode element is at a higher potential than said collector electrode, a layer of an insulating material on the outer surface of said anode element and between said anode element and the inner wall of said enlarged portion of said central bore, said anode element, insulating layer, and housing defining a condenser between said anode element and ground, means for applying a potential bias to said collector electrode positive with respect to said cathode, and means connected to said anode element for taking the signal therefrom.

10. A traveling wave tube in accordance with claim 9 wherein a choke coil is positioned within said aperture and connected to said collector electrode and said output means includes a high frequency choke coil connected to said anode element and a high resistance connected to said high frequency choke coil.

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